**Title.** Measuring the efficiency of health systems in Asia: A data envelopment analysis

**Short title.** Measuring the efficiency of health systems in Asia

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**ABSTRACT**

**Objective:** This study aims to estimate the technical efficiency of health systems of Asian countries.

**Settings:** The study was conducted based on Asian countries.

**Methods:** We applied an output-oriented data envelopment analysis (DEA) approach to estimate the technical efficiency of the health systems in Asian countries. The DEA model used as input per-capita health expenditure (all healthcare resources as a proxy) and as output cross-country comparable health outcome indicators (e.g. HALE at birth and infant mortality per 1,000 live births). A tobit regression model was used to observe the associated factors with the efficiency scores. A sensitivity analysis was performed to assess the consistency of these scores.

**Results**: The main findings of this paper demonstrated that about (86.9 %) of the studied Asian countries were inefficient with respect to using healthcare systems resources. Most of the efficient countries belonged to the high-income group (Cyprus, Japan, and Singapore) and only one country belonged to the low- and lower middle-income group (Bangladesh). In Asia, through efficiency gain, the high-, upper middle-, lower and lower- middle-income countries can improve health systems outcome by 6.6%, 8.6%, and 8.7% respectively using the existing level of resources. Population density, beds density, and primary education completion rate significantly influenced the efficiency score.

**Conclusion:** The results of this analysis showed inefficiency of the health systems in most of the Asian countries and imply that many countries may improve their health systems efficiency using the current level of resources. The identified inefficient countries could pay attention to benchmarking their health systems within their income group or other similar type of health system.

**Strengths and limitations of this study:**

* Data envelopment analysis was used to determine the extent of inefficiency in health systems across Asia.
* We extracted health systems level indicators from the widely used world development indicators database and World Health Organization open data repository
* Due to data availability, we used health system outcomes in addressing the health systems efficiency rather than true health systems output

**BACKGROUND**

In Asia, there are approximately 4.4 billion people spread across highly diverse countries, from economic powerhouse like China and Singapore to poorer economies such as Laos, Cambodia, and Myanmar (1). The continent is often cited as the fastest-growing and most dynamic region in the world. Over the past number of years, Asian societies have also made impressive progress in ensuring better healthcare services, especially those targeted towards improving maternal and infant health and increasing life expectancy (2). However, whether economic gains have translated to efficient health systems across the region is still not well studied.

It is important that the healthcare resources in Asia are used efficiently. Overall, government spending on healthcare is low compared to total health expenditure and furthermore it is often not focused on those who need it most (3). For example, in the South Asia region governments spend 31% of total health expenditure, which is more than one percent of gross domestic product (4,5). In many Asian countries, personal health expenses or out-of-pocket payments is a major cause of poverty (1,6). From a study of 11 Asian countries, it was found that high levels of out-of-pocket healthcare spending have pushed 78 million people into poverty annually (7). Aging populations and non-communicable diseases that are often preventable but expensive to treat (e.g. diabetes and cancers linked to tobacco) impose and will continue to impose heavy costs on households and public health budgets. Moreover, a major challenge for Asian countries is the control and prevention of different communicable diseases (e.g. HIV/AIDS, tuberculosis, and polio) due to the movement of people across borders and the exchange of goods (8).

In light of this, it is very important that the health systems of these countries are efficient in making use of their resources. The World Health Organization (WHO) has estimated that about 20% to 40% of total healthcare resources are being wasted per year among the WHO member countries due to inefficiency. Further, this rate is high in low-and-middle income countries (LMICs) (9). In Asia, the variation in efficiency across income settings can perhaps lead to lessons learned in addressing it. In order to address inefficiency, Asia's health systems can look toward different dimensions of performance such as their effectiveness, efficiency, access, equity, and quality (10). A great deal of practitioner and academic literature has analyzed the relationship between the efficient production of health services and universal health coverage (UHC) as well as the widespread importance of measuring overall health system performance (9,11).

Assessing the efficiency of healthcare systems is a difficult process as analyses often encounter methodological problems, particularly due to the need for appropriate and valid outcome indicators (12). Despite the empirical difficulties in applying efficiency concepts to health systems, efficiency can be measured on both micro and macro levels (13). Measuring health system efficiency at a macro-level is particularly important in order to understand health system performance across the globe and take required action to minimize inefficiency (11,14).

A number of studies have addressed healthcare efficiency in Americas (15,16), Western Europe (17,18) and Asia (19,20) to shed light on the efficiency of different national health systems. A systematic review on measuring efficiency related to several aspects of healthcare was performed by Hollingsworth et al. (21). Dimas et al. evaluated the productivity of Greek public hospitals and found that productivity changes were dominated by technical change (22). Zere et al. measured the technical efficiency and productivity of hospitals in South Africa, and examined the impact of hospital characteristics on efficiency and productivity (23).

In an international study of efficiency in 170 countries, it was observed that Asian countries were comparatively in the middle with respect to health system efficiency scores (24). This indicates that there is room for improvement to optimize health benefits from the available health sector resources. In this region, there are a number of studies at the country level to address health systems efficiency (25,26), but cross country comparison of the health system efficiency is limited (27).

Asian countries are not homogenous in terms of area, population, and economic conditions, however, they have public health functions and a number of their health system outcomes in common (28). Many of the countries share similar health systems problems, including inadequate resources for healthcare and a high burden of diseases due to the geographical contiguity, disease patterns, and social conditions. Understanding health systems efficiency in different Asian countries could promote shared learning and highlight key areas of best practice, as well as areas where improvement is needed. Furthermore, given geographical proximity and many strong relationships experienced with near-by countries, there is likely to be relative ease in the ability to practically understand, learn and apply nuance about healthcare systems from one country to another.

A study of the efficiency of health systems in this region will help to provide lessons through comparison across countries. This paper aims to achieve this goal through evaluating the technical efficiency and scale efficiency of the healthcare systems of selected Asian countries.

**METHODS**

This study employed Data Envelope Analysis (DEA) which is a commonly used non-parametric method for efficiency analysis. It was used for estimating technical and scale efficiency scores of the health systems of Asian countries.

**Input and output variables**

A main assumption of the DEA model used in our analysis was that in Asian countries, the selected health outcomes were dependent on the inputs of healthcare resources. We selected the input variables as proxies for the quantity of inputs that a country devotes to healthcare (i.e. health expenditure per capita); and outcome variables of the healthy life expectancy at birth (HALE) and infant mortality (per 1,000 live births). The relationship between health expenditure and outcomes considered here is consistent with the view that health expenditure has diminishing returns, or additional expenditure beyond a certain level has relatively smaller incremental effect on life expectancy or infant mortality (29). To be clear, reduction in infant mortality and increase in life expectancy signify improvement in the health outcomes of a country. Some studies have included life expectancy at birth as an outcome variable (31–33), however, it is argued that quality of life matters as much as, if not more than, quantity of life, and therefore life expectancy should be a weighted health quality measure. As a result, HALE has been incorporated as a proxy of health quality as the outcome of health systems. Also, it is important to note that instead of using the infant mortality directly in the DEA model, we used the inverse of infant mortality as the model assumes that inputs and outputs are isotonic (i.e. increased input reduces efficiency as well as increased output increases efficiency) (34). Without this correction, a higher infant mortality figure would have been said to incorrectly contribute to a better health system outcome.

**Data sources**

We used two main data sources: The World Health Organization data repository and World Development Indicators-2015 (WDI). According to the list of United Nation Statistics Division, there are 50 Asian countries and territories. Among these , 46 were used for this study (35). Four countries and territories (Hong Kong, North Korea, Macao, and West bank and Gaza) were excluded due to missing data of selected variables in the WDI database (5). However, selected variables for the study countries were not reported in WDI for every year. This problem is unavoidable in studies based on WDI data (36–38). Earlier studies adapted two approaches to deal with such problem. Firstly, they used a value from a slightly earlier year as in Anderson et al. (36) and secondly, they used a smaller number of countries in the model as in Fare et al. (37) and Grubaugh and Santerre (38). Given the importance of including as many countries as possible to study technical efficiency using Data Envelope Analysis, we opted for the first approach. However, to avoid missing variable we used slightly earlier WDI statistics.

**Data envelopment analysis**

DEA is one of the most widely used methods to assess the technical efficiency and scale efficiency of a set of decision-making units (DMUs) (In the case of this analysis, DMUs are the 46 different Asian countries). DEA is a non-parametric method which identifies an efficiency frontier on which only the efficient DMUs are placed, by using linear programming techniques. One type of DEA model, developed by  Charnes, Cooper, and Rhodes (CCR), assumes that production has constant returns to scale (CRS) meaning any change in the input will result in a proportionate change in the output (39). Another model proposed by Banker, Charnes, and Cooper (BCC), assumes that production has variable returns to scale (VRS) implying an increase in the input will result in either an increase or a decrease in the output. The latter methodology is particularly useful for this study since it aims to measure the efficiency related to organizational units (i.e. the health systems of the different countries), which use numerous resources to produce multiple outputs and accommodate a more flexible assumption of VRS (24,40). This is more realistic and reflective of changes in the real world (25).

Scale efficiency scores provide information on the optimality of the DMUs size. When a production unit (DMU) operates at CRS, technical efficiency is equal to scale efficiency. However, when DMUs are not operating at optimum scale, technical efficiency measured with the CCR model may be altered by scale efficiency. The BCC model, which defines production through VRS, can incorporate the impact of scale efficiency in the measurement of technical efficiency. This is measured as the ratio of CRS technical efficiency scores and VRS technical efficiency scores (41).

When it comes to DEA studies comparing countries, both the input and output oriented models have been adopted for this type of analysis. An output-oriented DEA model aims to maximize the outputs with a given amount of inputs; while input-oriented models focus on minimizing the inputs used to obtain a certain amount of output. Many studies have been carried out using DEA to assess the efficiency of healthcare systems using the two approaches in both high-income and low-income countries (42–45). In this study, an output-oriented DEA model was deemed more appropriate based on the premise that the input per capita expenditure is likely to be less flexible. In other words, health system stewards are likely to have more leverage in controlling outputs through innovative programming and improvements in healthcare provided, rather than by increasing spending and resources.

**Output oriented model**

The output-oriented technical efficiency model focuses on increasing output without changing the quantity of inputs used. The objective of the model for solving each particular DMU (country) is to maximize the efficiency score (denoted by ) meaning the amount by which all outputs can be improved for each country under consideration while holding input constant.

The output-oriented DEA model is specified as follows.

Subject to constraints

0

Where,

Yrj = amount of output r from country j,

Xij = amount of input i to country j,

Or = weight given to output r,

Vi = weight given to input i,

n = number of countries,

s = number of outputs,

m = number of inputs.

O0 > 0 defines increasing returns to scale, O0 = 0 defines constant returns to scale, and O0 < 0 defines decreasing returns to scale.

The technical efficiency scores is defined by and it ranges between 0.00 and 1.00, If it is equal to 1.00, then the production from the DMU is efficient; while if it is less than 1.00, the DMU is inefficient.

**Tobit regression analysis**

In the second stage, the VRS efficiency scores computed using the DEA model were regressed against some true inputs of the health systems (e.g. physician and beds density per 1000 population) and some environmental factors (Table 1). Since, by definition, the DEA scores range between zero and one, and some of the data tend to concentrate on these boundary values (i.e. censored for the DMUs with a value at one), ordinary least squares can not estimate the regression. Therefore, a tobit model is best for such regression. For the convenience of calculation, we assumed a censoring point at zero in this model. As a result, the efficient DMUs will have a score of zero and the inefficient DMUs will have score greater than zero. Following Zere at et. (46), we applied this method by transforming VRS technical efficiency scores into VRS inefficiency scores and leaving censoring at zero as follows.

The Tobit regression model used variables representing access to healthcare and health status. Guided by several similar studies, physician density (the number of physicians per 1,000 population) and bed density (the number of inpatient beds per 1,000 population) were selected as determinants of access to healthcare (38,47). In addition to health care, the health status of individuals is determined by the lifestyle and behaviors, therefore we also included two environmental factors as determinants of efficiency, namely smoking prevalence among adult male (percentage of adults) and primary education completion rate of relevant age group. The relevant age group for the primary completion rate is defined as the number of new entrants (enrolments minus repeaters) in the last grade of primary education (regardless of age); divided by the population at the entrance age for the last grade of primary education of a country (48). The adverse health effect of smoking consequently affects health outcomes (49,50). Education is found to be an important factor in determining individual health status. Higher educational attainment is associated with higher income which in turn secures a healthy living environment and access to healthcare (51). Additionally, we included population density (population living per square kilometre of land area) as the control of efficiency. This is because population density can affect the quality of healthcare services.

The Tobit regression models were specified as follows,

Where,

Ineff = the technical inefficiency score; continues variable.

Phy = Physician density; categorical variable (1= Fewer than 1 physician; 2= 1-2 physician, 3= More than 2 physician)

Beds =Beds density; categorical variable (1= Fewer than 1 beds 3= More than 1 and less than or equal to 3 beds, 3= More than 3 and less or equal to 5 beds, 4= More than 5 beds)

Inc= Income group of the country; categorical variable (1=Low income, 2=Lower-middle income, 3=Upper-middle-income, 4=High-income)

Pop\_density= Population density; categorical variable (1= Fewer than or equal to 50, 2= More than 50 to fewer than or equal to 100, 3= More than 100 to fewer than or equal 200, 4= More than 200)

Finally, εi was the stochastic error term.

**Sensitivity analysis**

A sensitivity analysis of the efficiency score was conducted by running the DEA model several times using different combinations of input and outcome variables. We considered multiple models (e.g. dropping the efficient countries, using HALE at age 60, current health expenditure per capita (current US$) as inputs. and using the complete set of data for the year 2015 (excluding countries with any missing variable)

**Patient and Public Involvement**

The study used secondary data from WHO and WDI data base. No patients were involved in this study. Study findings will be shared with the stakeholders, including local community groups in community meetings and at national or regional conferences.

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**RESULTS**

The descriptive statistics of the selected input, output and environmental variables are shown in Table 1. The health expenditure per-capita ranges from a minimum of 88.03 USD (Bangladesh) to a maximum of 4,405.13 USD (Japan) with a mean, median and standard deviation of 1,133.71, 663.94, and 1,157.72 respectively. The number of physicians per 1,000 people ranges from a minimum of 0.1 at Timor-Leste to maximum 4.8 at Georgia. However, the number of inpatient beds per 1,000 people is smallest in Iran (0.1) and highest in Japan (13.7). The average smoking prevalence of the adult male people among the studied countries is 42.2 and average primary education completion rate is 96.5% of the relevant age group.

Table 1. Descriptive statistics of input and output variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Characteristics/ description** | **Mean** | **Median** | **SD\*** | **Minimum** | **Maximum** | **Source** |
|  |  |  |  |  |  |  |
| **Input variables** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Health expenditure per capita, PPP | 1,133.71 | 663.94 | 1,157.72 | 88.03 | 4,405.13 | WDI |
| **Outcome variables** |  |  |  |  |  |  |
| Healthy life expectancy at birth (years) | 64.29 | 65.2 | 5.1 | 53.2 | 75.9 | WHO |
| Infant mortality (per 1,000 live births) | 19.9 | 13.9 | 15.8 | 2.0 | 65.7 | WDI |
| **Explanatory variables for Tobit model** |  |  |  |  |  |  |
| Physicians (per 1,000 people) | 1.6 | 1.6 | 1.1 | 0.1 | 4.8 | WDI |
| Hospital beds (per 1,000 people) | 2.9 | 2.1 | 2.7 | 0.1 | 13.7 | WDI |
|  |  |  |  |  |  |  |
| Smoking prevalence,  males (% of adults) | 42.2 | 42.2 | 10.5 | 18.9 | 71.8 | WDI |
| Primary completion rate,  total (% of relevant age group) | 96.5 | 97.9 | 11.4 | 66.7 | 116.5 | WDI |

\*Standard deviation

Among the countries analyzed, HALE at birth was a minimum of 53.2 years in Afghanistan and a maximum of 75.9 years in Singapore. The infant mortality rate ranged from 2.1 deaths per 1,000 live births in Japan to 68.1 deaths per 1,000 live births in Afghanistan. On average, there were 21.1 deaths per 1,000 live births in the studied countries. The scatter matrix of the input and output variables shows that inputs, for instance, increase in per-capita healthcare expenditure was associated with improved health outcomes (e.g. HALE at birth and reduced infant mortality) (Figure 1).

(Figure 1. will be inserted here)

The mean CRS and VRS technical efficiency scores were 0.780 and 0.921 respectively (Table 2). Whereas, the mean scale efficiency score was 0.874. Considering VRS efficiency, Afghanistan has the lowest score of 0.766 and 0.812. Both VRS and CRS technical efficiency score were positively correlated with per capita health expenditure, HALE at birth, and negatively correlated with infant mortality (supplementary table 1).

Out of 46 countries studied, only 4 (8.7%) countries showed the maximum level of (efficiency score 1.00) in VRS and CRS technical efficiency scale. All of these four countries showed scale efficiency of 1.00 implying that these countries created the best practice frontier based on their input and output combinations. 39.1% (18) countries showed increasing returns to scale, 52.2% (24) countries decreasing returns to scale, and the 4 efficient countires constant returns to scale production function of their health systems.

(Table 2. will be inserted here)

More than half of the countries (30 countries) had VRS efficiency and five countries CRS efficiency greater than 90% (supplementary figure 1).

**Tobit regression analysis of associated factors with inefficiency**

Tobit regression was employed to relate the VRS inefficiency scores to two health service production variables and four environmental variables. Physician density, income status of countries, and smoking prevalence among males exhibited a statistically insignificant positive association with the inefficiency scores. The density of bed (>3 and <=5) had a significantly negative association with the inefficiency scores compared to less than 1 beds category. Countries having more than 5 beds density had no significant association with the inefficiency scores. After the bootstrapping more than 5 beds density showed significant association with inefficiency score (supplementary table 2). However, the coefficient was highest for (>3 and <=5) beds density. This indicates that sample countries with less than 1 bed have lower technical efficiency of its health systems. Furthermore, the primary education completion rate was significantly negatively associated with the inefficiency score which indicates that countries with higher percentage of primary education completion rate have higher health system efficiency. Population density had a significantly negative association with the inefficiency score. Countries having less than 200 population per square kilometre were found to have lower efficiency.

**Sensitivity of the efficiency scores**

We conducted sensitivity analysis using various combinations of input and output variables. In all of these cases the average of the efficiency scores varied from 0.812 to 0.936. The most sensitive combination was found while using the HALE at age 60 as the input variable. The efficiency score changed from 0.919 (main model) to 0.812 (considering input as HALE at age 60) (Figure 2).

(Figure 2. will be inserted here)

In Table 3, mean efficiency scores are presented by the income categories of the countries. The highest mean VRS technical efficiency were observed for high income countries (0.934; 95% CI 0.905-0.963), followed by upper-middle-income (0.914; 95% CI: 0.894-0.935), and low and lower-middle income countries (0.913; 955% CI: 0.891-0.935). With the existing input levels, the high-, upper middle-, low- and lower-middle income countries could improve their health system outcome by 6.6%, 8.7%, and 8.7% respectively.

Table 4. Mean efficiency scores according to income level of Asian countries

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Income groups** |  | **VRS technical efficiency** | | | **Percentage of output can be improved in CRS technical efficiency** |
|  |  | **Mean** |  | **95% CI** |  |
| Low- and lower middle-income |  | 0.913 |  | (0.891-0.935) | 8.7% |
| Upper middle-income |  | 0.914 |  | (0.894-0.935) | 8.6% |
| High -income |  | 0.934 |  | (0.905-0.963) | 6.6% |

**DISCUSSION**

The main findings of this paper demonstrated that about (86.9 %) of the studied Asian countries are technically inefficient with respect to using healthcare systems resources, (using a proxy of per capita health expenditure). The study findings showed that the most efficient countries belonged to the high-income group (Cyprus, Japan, and Singapore). Only one country belonged to the low- and lower middle income group (Bangladesh). Among the 46 countries studied, only four countries (Bangladesh, Japan, Singapore, and Cyprus) showed constant returns to scale efficiency, indicating that they were operating at their most efficient level. Of the 14 high-income countries studied, 9 countries (75.0%) had health system production at decreasing returns to scale. This implies that although the highest number of efficient countries belonged to the high-income group, a large number of these countries health system production requires more resources than the ideal situation. A similar situation was observed for the upper-middle-income countries. Of the 13 countries, 10 (76.9%) had decreasing returns to scale. Only 5 (23.8%) out of 21 low – and lower-middle-income countries were producing at decreasing returns to scale. Although these low- and lower-middle-income countries are not efficient, most of their production follows increasing returns to scale.

It was observed that the average of the efficiency scores increased from the low and lower-middle-income countries to high-income countries. An important policy implication of this study could be that the technically inefficient low-income countries on average can improve their health systems outcome by 8.7%, middle income country by 8.6%, and high income country by 6.6% using the existing levels of per-capita health expenditure. An international study found a similar conclusion that health systems performance is most efficient in the developed countries, according to simple efficiency scores (52).

The overall healthcare efficiency in different countries varied considerably (53,54). Among the low-and lower-middle income studied, one country demonstrated the most efficient health systems (Bangladesh). This county has both technical and scale efficient health systems, like the high-income countries (Japan, Singapore, and Cyprus) (55). A possible reason for the high efficiency of these LMICs could be a focus on infant mortality and child health as prioritized in past Millennium Development Goals and in current Sustainable Development Goals agendas, which relates to the outcome variables used in this study.

The DEA result showed that more than 60% of the low- and lower middle income countries had health system efficiency greater than 90%. This result implies that these countries produce good health at low cost and therefore make good use of health systems resources (56). This result suggests that it is possible for countries to have a high-efficiency score with poor health outcomes because of their low expenditure on resources and increasing returns to scale production function. In other words, given their moderate consumption of inputs and challenging social environments, these countries can achieve good health outcomes, relative to the other countries. Similar findings were observed for Mexico and Turkey relative to other countries in a study of the OECD countries (33). It should be noted that this study only used per-capita health expenditure and there are other factors that influence health outcomes as well. For example differences in life expectancy and infant mortality between populations can be due to lifestyles, preferences (49,57,58) social class, occupation (59) and environmental factors (60,61). On a more macroscopic level, the results could also be impacted by a variety of contextual factors among countries such as different political institutions, economic landscapes, health-seeking behavour patterns and burden of diseases among other things. However, in this study, we attempted to address by including variables addressing the number of physicians, number of inpatient beds, and population density, along with two environmental factors namely primary completion rate of relevant age group and smoking prevalence among the adult male population to take into consideration some of this variation. The results showed that more than three and less than five beds per 1000 population significantly influenced the efficiency score. A low number of beds cannot serve a large proportion of the population and therefore the systems may be inefficient. Similarly, a high number of beds may often be left unused and make the health systems inefficient The countries having more than 200 people living per square kilometre had a higher level of efficiency in their health systems.

A limitation of DEA methodology is that it works in a deterministic way, meaning that the results entirely depend on the numeric values in the dataset. As the DEA approach compares DMUs, the number and nature of DMUs in the data set can noticeably change the results. For example, if a more efficient country is added to the dataset, it would move the frontier, causing some of the efficiency scores of other countries to fall. This is a key aspect of the methodology used.

Additionally, it is important to note that the use of a different set of variables might have generated different conclusions. In the future, if additional data become available for a larger number of countries in the region, the number of variables analyzed could be increased to include an understanding with a greater degree of complexity in health system efficiency.

Another data limitation is the comparability of health expenditures among the Asian countries. While recognizing that it is not possible to solve the inherent issues, we made an attempt to minimize it. Since the actual amount of healthcare expenditure across different countries may not be comparable due to the difference in purchasing power parity across countries, we used health expenditures as constant of 2011 in PPP as an input in the DEA model (33). Also, when we included health expenditure at current USD per capita as an input in the DEA model we found that the efficiency score did not change significantly.

We applied sensitivity analysis to in an attempt overcome these limitations (Figure 2.) Our results were consistent while using several combinations of inputs and outputs variables which is reassuring and strengthens the findings from this study.

**CONCLUSIONS**

This study provides an empirical picture of the technical efficiency of the healthcare systems of 46 Asian countries. It found that inefficiency exists in the healthcare systems of most of the countries studied, however, the results point to three high-income and one low- and lower-middle-income country which efficiently used healthcare systems resources. The interpretation of the inefficient countries identified through this study is that they can improve health outcomes using the current level of per-capita health expenditure. These countries could use these results to direct their attention to benchmarking their health systems within their regional or another comparative group in order to understand their health system performance in a more detailed way. This study addresses the need to understand issues of efficiency, as well as potentially identify good examples of countries which efficiently allocate and use resources to make their healthcare systems more technically efficient. It narrows a gap in the literature as there are few countries studying healthcare efficiency in Asia and looking comparatively in this manner.

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**Contributors**

SA, MZH and MM contributed to conceptualizing the research idea, study design, literature search, data extraction and analysis, data interpretation, and writing the manuscript. MWA FD, SMH, MMH, MTI and JAMK contributed to writing, reviewing and revising the manuscript. All authors read and approved the final manuscript.

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**Competing interest**

None declared**.**

**Data sharing statement**

Data were extracted from the World Bank Open Data repository for the “World Development Indicators’ and from World Health Organization Global Health Observatory data. The following links was used to extract the excel format of the indicators: <https://data.worldbank.org/> and <http://www.who.int/gho/en/>.

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**Tables**

Table 2. Technical and scale efficiency score of the health systems in Asian countries

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country name** | **CRS Technical efficiency** | **VRS Technical efficiency** | **Scale efficiency** | **Returns to scale** |
| Afghanistan | 0.724 | 0.812 | 0.891 | 1 |
| Armenia | 0.769 | 0.946 | 0.813 | -1 |
| Azerbaijan | 0.660 | 0.902 | 0.732 | -1 |
| Bahrain | 0.714 | 0.910 | 0.784 | -1 |
| Bangladesh | 1.000 | 1.000 | 1.000 | 0 |
| Bhutan | 0.775 | 0.903 | 0.858 | 1 |
| Brunei Darussalam | 0.708 | 0.920 | 0.769 | -1 |
| Cambodia | 0.805 | 0.916 | 0.879 | 1 |
| China | 0.806 | 0.975 | 0.826 | -1 |
| Cyprus | 1.000 | 1.000 | 1.000 | 1 |
| Georgia | 0.751 | 0.923 | 0.813 | -1 |
| India | 0.778 | 0.892 | 0.872 | 1 |
| Indonesia | 0.746 | 0.904 | 0.826 | 1 |
| Iran | 0.678 | 0.900 | 0.754 | -1 |
| Iraq | 0.683 | 0.850 | 0.803 | 1 |
| Israel | 0.874 | 0.967 | 0.904 | -1 |
| Japan | 1.000 | 1.000 | 1.000 | 0 |
| Jordan | 0.743 | 0.943 | 0.789 | -1 |
| Kazakhstan | 0.695 | 0.882 | 0.788 | 1 |
| South Korea | 0.886 | 0.972 | 0.911 | -1 |
| Kuwait | 0.674 | 0.885 | 0.762 | -1 |
| Kyrgyz Republic | 0.806 | 0.941 | 0.856 | 1 |
| Laos | 0.818 | 0.889 | 0.920 | 1 |
| Lebanon | 0.746 | 0.910 | 0.820 | 1 |
| Malaysia | 0.778 | 0.927 | 0.839 | 1 |
| Maldives | 0.730 | 0.944 | 0.773 | -1 |
| Mongolia | 0.737 | 0.896 | 0.823 | 1 |
| Myanmar | 0.743 | 0.872 | 0.852 | 1 |
| Nepal | 0.861 | 0.932 | 0.924 | 1 |
| Oman | 0.692 | 0.896 | 0.772 | -1 |
| Pakistan | 0.827 | 0.889 | 0.930 | 1 |
| Philippines | 0.779 | 0.916 | 0.850 | 1 |
| Qatar | 0.677 | 0.903 | 0.749 | -1 |
| Saudi Arabia | 0.624 | 0.871 | 0.716 | -1 |
| Singapore | 1.000 | 1.000 | 1.000 | 0 |
| Sri Lanka | 0.904 | 0.985 | 0.917 | -1 |
| Syria | 0.818 | 0.848 | 0.964 | 1 |
| Tajikistan | 0.856 | 0.964 | 0.888 | -1 |
| Thailand | 0.791 | 0.956 | 0.828 | -1 |
| Timor-Leste | 0.823 | 0.903 | 0.912 | 1 |
| Turkey | 0.710 | 0.916 | 0.776 | -1 |
| Turkmenistan | 0.639 | 0.859 | 0.743 | 1 |
| United Arab Emirates | 0.691 | 0.889 | 0.777 | 1 |
| Uzbekistan | 0.784 | 0.947 | 0.828 | -1 |
| Vietnam | 0.845 | 0.996 | 0.849 | -1 |
| Yemen | 0.727 | 0.826 | 0.881 | 1 |
| **Mean (95% CI)** | **0.780**  **(0.752-0.808)** | **0.919**  **(0.905-0.933)** | **0.847**  **(0.824-0.87)** | **-** |
| **Median** | 0.772 | 0.913 | 0.834 | - |
| **Minimum** | 0.624 | 0.812 | 0.716 | - |
| **Maximum** | 1 | 1 | 1 | - |

Table 3. Result from tobit regression analysis

|  |  |  |
| --- | --- | --- |
| **Variable** | **Coefficient (95% CI)** | **P-value** |
| **Physician density (per 1,000 population)** |  |  |
| Fewer than 1 physician |  |  |
| 1-2 physician | -0.0005 (-0.0363,0.0353) | 0.9780 |
| More than 2 physician | -0.0003 (-0.0445,0.044) | 0.9900 |
| **Bed density (per 1,000 population)** |  |  |
| Fewer than 1 beds | 1.000 |  |
| More than 1 and less than or equal to 3 beds | -0.0146 (-0.0558,0.0267) | 0.4770 |
| More than 3 and less or equal to 5 beds | -0.0398 (-0.0852,0.0055) | 0.0830 |
| More than 5 beds | -0.0412 (-0.0917,0.0092) | 0.1060 |
| **Primary completion rate, total (% of relevant age group)** | -0.0018 (-0.003--0.0007) | 0.0030 |
| **Smoking prevalence, males (% of adults)** | 0.0002 (-0.0012-0.0016) | 0.7470 |
| **Income group** |  |  |
| Low income | 1.00 |  |
| Lower-middle income | -0.0367 (-0.1041-0.0306) | 0.2750 |
| Upper-middle-income | -0.0240 (-0.0986-0.0506) | 0.5170 |
| High-income | -0.0279 (-0.107-0.0513) | 0.4790 |
| **Population live per square kilometre of land area** |  |  |
| less than or equal to 50 | 1.000 |  |
| >50 to <=100 | -0.053 (-0.0892--0.0168) | 0.0050 |
| >100 to <=200 | -0.0678 (-0.1071--0.0285) | 0.0010 |
| More than 200 | -0.0867 (-0.1224--0.0509) | 0.0000 |
| Constant | 0.3623 (0.2233-0.5014) | 0.0000 |
| Sigma | 0.0394(0.0305-0.0484) | - |
| Observations summary | 4 left-censored observations 42 uncensored observations 0 right-censored observations |  |
| Number of observation | 46 | - |
| Log likelihood | 71.4 | - |
| Prob. > chi2 | 0.000 | - |

**Figures**

Figure 1. Association across health systems input and outcome



Figure 2. Results from the sensitivity analysis of efficiency scores

